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Hierarchy Analysis of Water Demand Among Hotel Consumers for Water Appliances

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Abstract: The sustainable management of domestic water use is essential for China's ongoing development. Despite its significance, public service water use, especially within the hotel industry, is frequently neglected. This industry not only accounts for substantial water usage, but it has also witnessed exponential growth over the past decade. In light of this, this study developed a survey on the water demand and behavior of hotel consumers and built a water consumption model to analyze the different characteristics of the total volume of water used by various water appliances. Furthermore, by dividing the hierarchical intervals of each water-use behavior, it identified the main water-saving target of each water appliance. The results showed that the daily water demand of each consumer in hotels ranged from 45 to 141 L/(person·d). Among the various water-use appliances, faucets had the highest proportion of excessive water use, reaching nearly 40%, which implies a relatively large potential for saving water. Additionally, showers were the next major contributors to water consumption, whereas the proportion of excessive water use for water closets was relatively small. Owing to different habits, there is also variability in the main groups of people targeted for water conservation across water appliances, with females having the largest potential for water consumption in hotels. The results of this study can provide greatvaluable insights for enhancing water-use efficiency in hotels and standardizing water management practices within the industry.

Keywords: water use hierarchy; terminal water appliances; water management

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1. Introduction

Although China is the sixth-largest holder of water resources globally, its per capita share is a mere 35% of the global average, with nearly two-thirds of its cities experiencing varying degrees of water scarcity. This water shortage has emerged as a substantial constraint on China's economic and social development. In 2022, China's total water use reached 5998.2 billion cubic meters, a 2% decrease from 2012 [1]. With little significant growth in water usage for industrial and agricultural purposes, domestic water use has become the primary driver of increased water demand. From 2012 to 2022, domestic water use rose from 741.9 billion to 905.7 billion cubic meters—an increase of 22.1% [2]. With future urban development and further improvements in the living standards of residents, domestic water use is likely to remain a key factor in driving water demand growth [3]. Therefore, managing the rapid increase in domestic water use is crucial for sustainable social development.

Addressing water scarcity requires effective demand management strategies for water resources. Many countries have implemented policies for water resource management, leading to studies that investigate the impact of these policies, such as water conservation policies [4] and water pricing [5–7]. In fact, not all water resource management policies are effective. In Ethiopia, water consumption increased from 43 L/(person·d) pre-policy

to 72 L/(person·d) post-policy from 2010 to 2020, implying that the government must engage with local stakeholders in the process of revising the current policy documents [8]. Moreover, a growing body of research is examining how the unique characteristics and behavioral diversity of residents affect water demand, including factors such as [9,10] family demographic structure [11,12], water conservation awareness of residents [13,14], and water-use appliances [15–17]. A case study in Malaysia shows local people's behavior and daily activities that led to changes in water demand, finding that the demographic factors affecting the number of households influence the average monthly water bill of households in compared to other factors such as age, gender, race, and education level [18].

To enhance water use efficiency and alleviate water resource pressure, the hierarchical water demand theory for human survival proposed by the World Health Organization (WHO) [19]—in conjunction with water resource needs for normal human life, which is divided into three levels: short-term survival, medium-term maintenance, and long-term sustainability, as an important theory guiding the rational use of water resources—has received widespread attention. Based on Maslow's hierarchy of needs theory [20], the aim is to maximize water resource utilization and benefits by classifying water demand into different levels while ensuring the satisfaction of basic life needs. Currently, Maslow's hierarchy of needs theory is widely applied in psychology and management, with relatively few studies on water resource management or demand research. Israeli scholars have divided water resource management into five levels, ultimately aiming to achieve a sustainable hierarchy of water resource demands while emphasizing that the needs and concerns of residential water use should be fully considered at every stage [21]. Currently, the application of the water hierarchy theory by Chinese scholars is mostly concentrated on the stages of water resource utilization and management, including aspects such as lake ecosystems [22], water resource development and utilization [23], water hierarchy management in the Dianchi Lake Basin [24], and water resource management forecasting [25]. Zhao et al. [26] were the first to apply this theory to residential water use, dividing demand into three levels: rigid, flexible, and luxurious.

Domestic water use includes both household water use and public service water use. In 2022, public service water use in urban areas of China accounted for 14.5% of the total urban water supply, reaching 98.1 billion cubic meters—a 37.9% increase from 2012. However, previous research on water demand management and the hierarchy of water demand has mainly focused on household water use, with less attention given to public service water use. The hotel industry, in particular, has seen significant growth and high water use over the past decade, with the number of rooms and beds increasing by 35.4% and 30.4%, respectively, from 2012 to 2022 [14]. Therefore, this paper attempts to analyze water management in the hotel industry from the perspective of hotel consumers' water usage. It contributes to existing research by making a novel application of the hierarchical water demand theory to this sector. Based on extensive questionnaire surveys, it focuses on the water usage behavior of hotel consumers, establishing hierarchical intervals for almost all major activities, including bathing, washing up, hand washing, and toilet flushing. This can facilitate a better understanding of water usage patterns and identify the potential for water savings in the hotel industry. Given the rapid growth of the hotel industry in recent years, this paper has the potential to contribute significantly to water conservation efforts across society. Furthermore, the establishment of a norm of water intake national standard for various industries is a critical component of sustainable water management in China. The findings of this paper can substantially support the development of such standards for the hotel industry, thereby fostering more sustainable water management in the country.

The rest of the paper is organized as follows: Section 2 offers a systematic description of the data and the research methodology employed in this paper. Section 3 presents a detailed analysis of the study's results. In Section 4, these results are further discussed and compared with the findings from existing studies. The conclusions drawn from the study are presented in Section 5, while Section 6 discusses the limitations of this paper.

2. Materials and Methods

2.1. Flowchart Methodology

The research on the water demand of hotel consumers based on the water usage hierarchy theory is carried out in accordance with Figure 1.

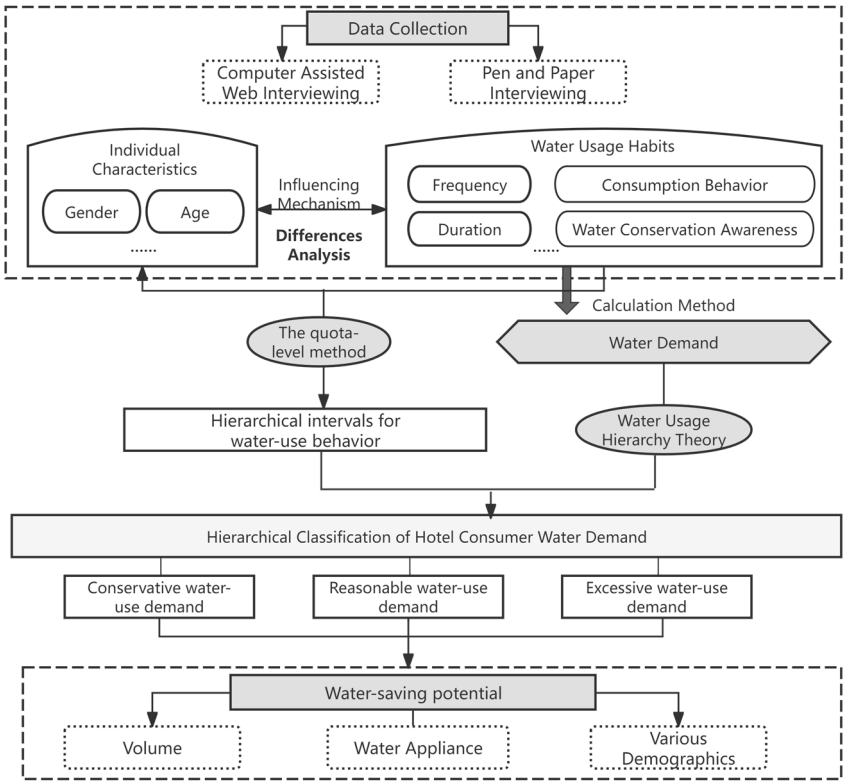


Figure 1. Flowchart methodology.

2.2. Data Collection

This study conducted a survey on the water-use behavior of hotel consumers using a questionnaire that included information such as gender, age, and other basic information about hotel consumers, as well as their awareness of water conservation, check-in habits, and personal water-use habits. The mixed methodology was employed to ensure the collection of comprehensive and representative data. To facilitate easier recovery and analysis of the questionnaires, both computer-assisted web interviews (CAWI) and traditional paper-and-pencil interviews were utilized. This approach allowed for a broader reach and accommodated various respondent preferences, enhancing the overall efficiency and effectiveness of the data collection process. Since hotel consumers represent a diverse distribution, the questionnaires prepared after expert consultation was distributed randomly using the mixed sampling method.

2.3. Analysis Methods

2.3.1. Water Demand Model of Hotel Consumers

Consumer water use in hotels is primarily concentrated in the guest rooms, including fixtures such as showers, water closets, and faucets. The correspondence between each water-use behavior and the terminal water-use fixtures is shown in Figure 2. This study developed a water demand calculation method for hotel consumers based on the survey data on bathing, toilet flushing, personal hygiene, and other water-use habits. We calculated the water consumption for each behavior using Formulas (1)–(4).

$$V = V_s + V_f + V_h \quad (1)$$

$$V_s = I_s \times E_s \times F_s \times T_s \quad (2)$$

$$V_f = I_f \times E_f \times F_f \quad (3)$$

$$V_h = I_h \times E_h \times \left(\sum_{i=1}^{2} F_{hi} \times T_{hi}\right) \quad (4)$$

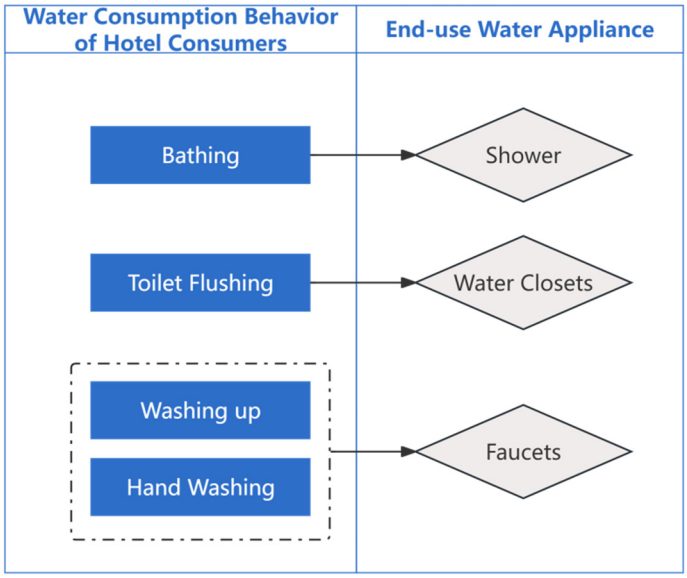


Figure 2. Correspondence of hotel consumer water behavior and terminal water appliance.

In the formula, V represents the total water consumption by consumers in the hotel [L/(person·d)]; V_s, V_f, and V_h represent water consumption for the shower, water closet, and faucet respectively [L/(person·d)]; I_s, I_f, and I_h represent the usage status of the shower, water closet, and faucet (0/1 values, where 1 indicates use and 0 indicates no use); E_s, E_f, and E_h represent the water efficiency levels of the shower, water closet, and faucet, determined using grade 2 in the National Standard, which sets the minimum allowable values of water efficiency and water efficiency grades for water-using appliances [27–29]; F_s and T_s represent the frequency of use and duration of the shower; F_f represents the frequency of water closet use; F_{hi} (i = 1, 2) represents the frequency of washing up and hand washing, respectively; and T_{hi} (i = 1, 2) represents the duration of water faucet use for washing up and hand washing, respectively.

2.3.2. Hierarchical Classification of Hotel Consumer Water-Use Behavior

The quota-level method [30] is based on the concept of probability density and reflects the extent of variation in the various influencing factors that achieve a certain quota within a given period. The value range of the quota level is between zero and one, with the magnitude of the value indicating the proportion of cases that meet a certain quota requirement; that is, the probability of occurrence. For example, a quota level of 0.6 indicates that there is a 60% probability of meeting this quota requirement. The selection of the quota level first requires summarizing and calculating the water-use data to determine the average value v and standard deviation s for each sample category. The quota level is then calculated using Formula (5).

$$Q = v + Z_\alpha s \quad (5)$$

where Z_α represents the value corresponding to the standard normal distribution probability density at the quota level of $(1 - \alpha)$, v represents the average value, and s represents the standard deviation.

This method has been primarily applied to demand analysis and quota settings for complex and diversified energy and water-use structures [31–33]. The study employed the quota-level method to categorize water-use behavior, using the water quota level

that 0.2 of consumers could meet as the standard for water-saving behavior, the water quota level that 0.8 of consumers could meet as the standard for reasonable water-use behavior, and water-use behavior above the quota level of 0.8 of consumers is excessive water-use behavior.

2.3.3. Hierarchical Classification of Hotel Consumer Water Demand

Referring to the series of water consumption values and the hierarchical evaluation method for different water-use behaviors in urban residential water use for frequency analysis [26], performing an analysis on the water consumption of a specific water-use behavior of hotel consumers, including the frequency of bathing, toilet flushing, washing up, and hand washing, and the duration of each water-use behavior, can yield the probability density (Figure 3). By integrating the probability density, the water consumption of hotel consumers can be categorized into intervals of conservative, reasonable, and excessive water use.

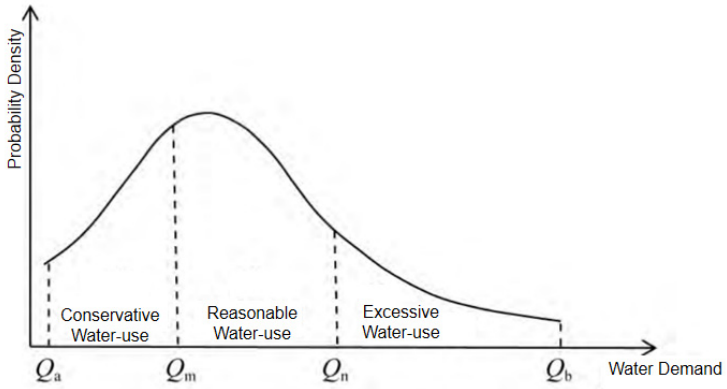


Figure 3. Schematic of the probability distribution and hierarchy of water use by hotel consumers.

3. Results

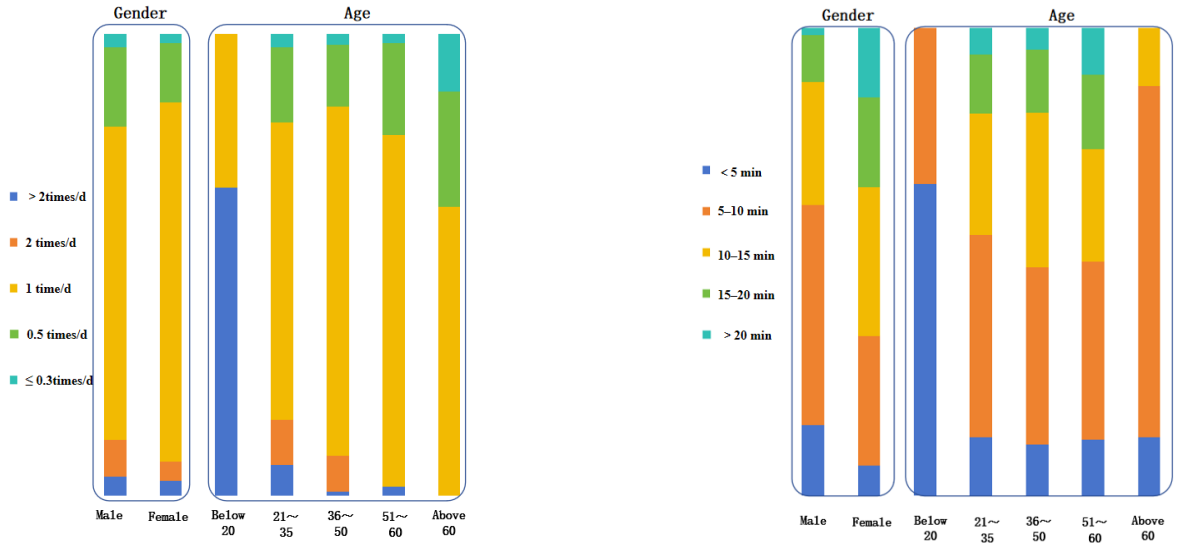
3.1. Data Analysis

In the valid sample, 292 questionnaires were collected, and all respondents voluntarily decided to answer the questionnaire. In the valid sample data, the ratio of male to female respondents was 68% to 32%. Seventy-nine percent of the surveyed population was between the ages of 21 and 50 years, 17% was between 51 and 60 years, and an extremely small number of respondents were under 20 or over 60 years of age; the proportions are 1% and 3%, respectively. The group of people participating in the survey included individuals who stayed in various types of hotels for different travel purposes, such as visiting relatives and friends, business trips, and leisure travel. Besides, the individuals span various provinces and regions across China, including the North-east, North, Central, East, South, Northwest, Southwest, etc.

3.2. Usage Habits of Primary Water-Using Appliances

Shower usage habits primarily consist of bathing frequency and duration. Based on the survey data analysis, as depicted in Figure 4, only 2% of consumers opted to use a bathtub for soaking while staying at hotels, predominantly comprising male consumers aged 36–50. The bathing frequency for hotel consumers is concentrated at once per day, with over 80% of shower durations falling between 5 and 20 min. Upon analyzing the bathing habits of consumers, notable differences were observed in bathing frequency and the time of shower activation per bathing, which were associated with individual characteristics such as gender and age. The findings indicate that female consumers bathe more frequently and for longer periods compared to their male counterparts, with an average shower duration 1.36 times longer than that of male consumers. As consumer age increased, there was a general decline in both bathing frequency and duration. Nearly 13% of consumers over the age of 60 have a bathing frequency of 0.3 times per day, with individual shower durations

all under 15 min; in contrast, consumers under 20 years of age exhibit significant differences in their bathing habits from those in other age brackets, showing an increased frequency of bathing and markedly reduced duration per shower session.



(**a**) Bathing frequency (**b**) Duration of per bathing

Figure 4. Analysis of differences in behavioral habits of showering.

The usage behavior of water closets is assessed based on the frequency of toilet flushing; eighty-five percent of consumers use the water closet two to four times a day while staying in hotels. The flushing frequency of female consumers was notably higher than that of male consumers. Consumers who are under 20 and over 60 years old often travel for purposes such as visiting relatives and friends or leisure tourism, resulting in shorter stays at hotels and, consequently, fewer demands for toilet flushing. Further details are shown in Figure 5.

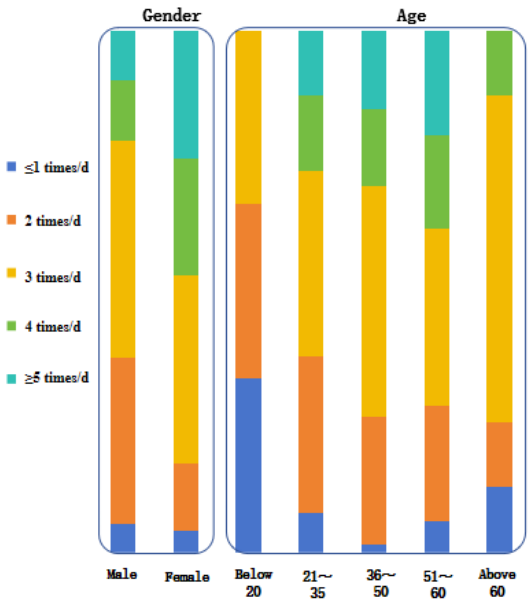
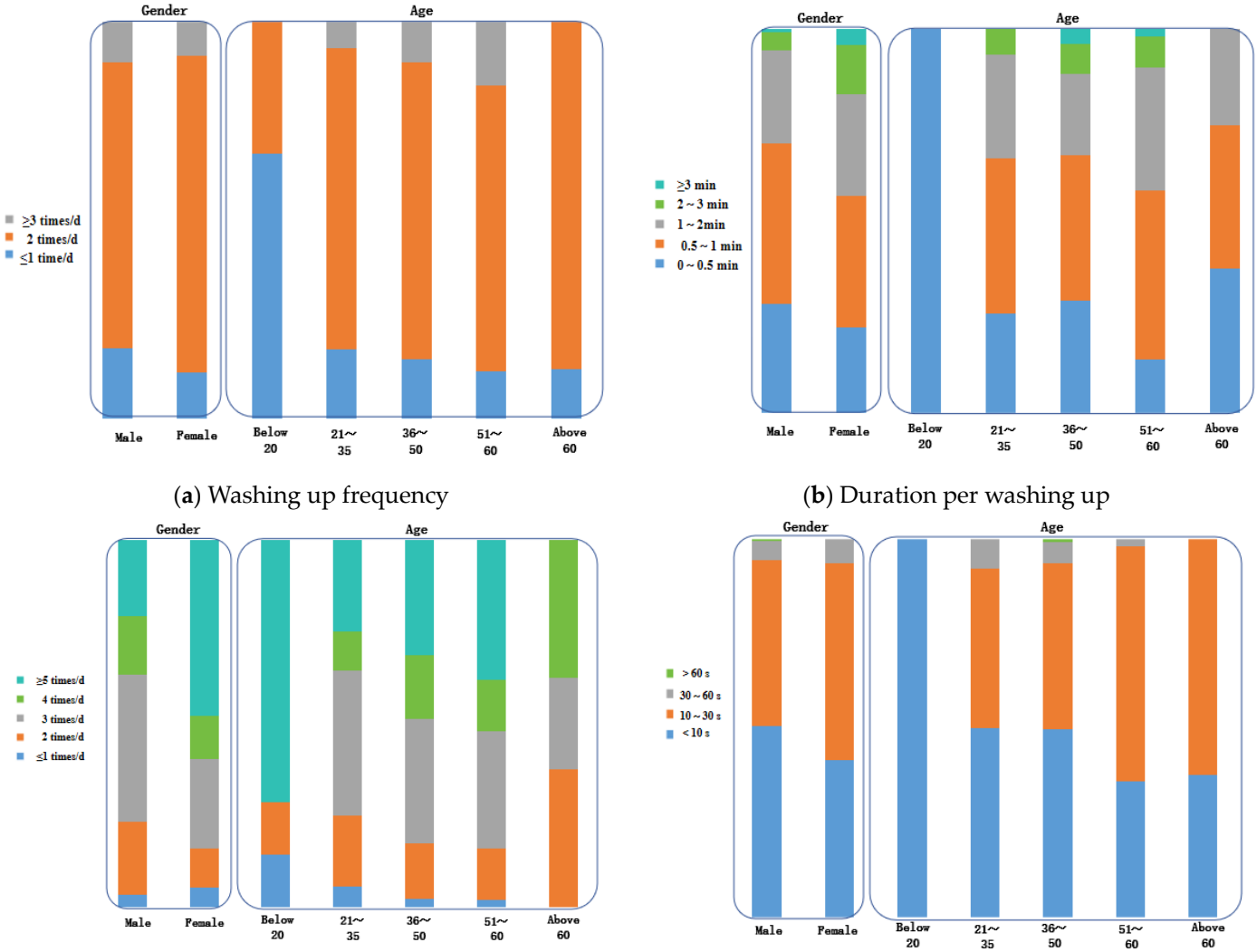


Figure 5. Analysis of differences in water closet behavioral habits.

The water-use behavior of hotel consumers regarding faucets is primarily categorized into two activities: washing up and hand washing, which are characterized by their

frequency of use and duration per instance. The frequency of washing up was similar among consumers of different genders, with nearly 80% washing up twice daily. However, the average duration for washing up was approximately 1.30 times longer for female consumers compared to male consumers, at 0.89 min and 1.16 min, respectively. Individuals under 20 years of age often washed up no more than once a day at hotels, whereas over 70% of consumers from other age groups washed up twice a day. Consumers who wash up more than three times per day are predominantly between the ages of 21 and 60. The average duration of washing up per session increased with age, peaking at 0.94 min per session for individuals aged 36 to 50 years, and then gradually decreased, with consumers over 60 years old averaging a washing up duration of 0.75 min. Hand washing more than five times a day was primarily observed among female consumers and those under 20 years of age, whereas consumers over 60 years of age exhibited a relatively lower frequency of hand washing, averaging three times per day. The duration of each handwashing session was relatively consistent, with approximately 95% of consumers taking less than 30 s per session, particularly among consumers under 20 years of age, who often wash their hands for less than 10 s per session. Further details are shown in Figure 6.



(**a**) Washing up frequency

(**b**) Duration per washing up

(**c**) Hand washing frequency

(**d**) Duration per hand washing

Figure 6. Analysis of differences in behavioral habits of faucets.

3.3. Water Demand Analysis

Calculate the water consumption of each water appliance according to Formulas (1)–(4), and the Cronbach's α coefficient value is 0.728, which indicates that the result is acceptable

in terms of reliability. The proportion of water consumption for each behavior by hotel consumers is shown in Table 1. The water consumption generated by the use of showers by consumers in hotels was the highest, accounting for approximately 63%; the water consumption of the other appliances was roughly equivalent.

Table 1. Proportion of water consumption by end-use appliances of hotel consumers.

Shower	Water Closet	Faucet	
		Washing Up	Hand Washing
62.67%	18.93%	12.67%	5.73%

Further statistical analysis of the series of values for various water appliance behaviors of hotel consumers yielded a normal distribution probability density for the water consumption of each appliance, as depicted in Figure 7. Based on the analysis, the water demand of hotel consumers is shown to be fundamentally normally distributed, with daily water usage predominantly ranging from 45–141 L/(person·d). Nevertheless, a small fraction of water-use behaviors is wasteful, accounting for approximately 12%, with the peak daily water consumption amounting to 333 L/(person·d).

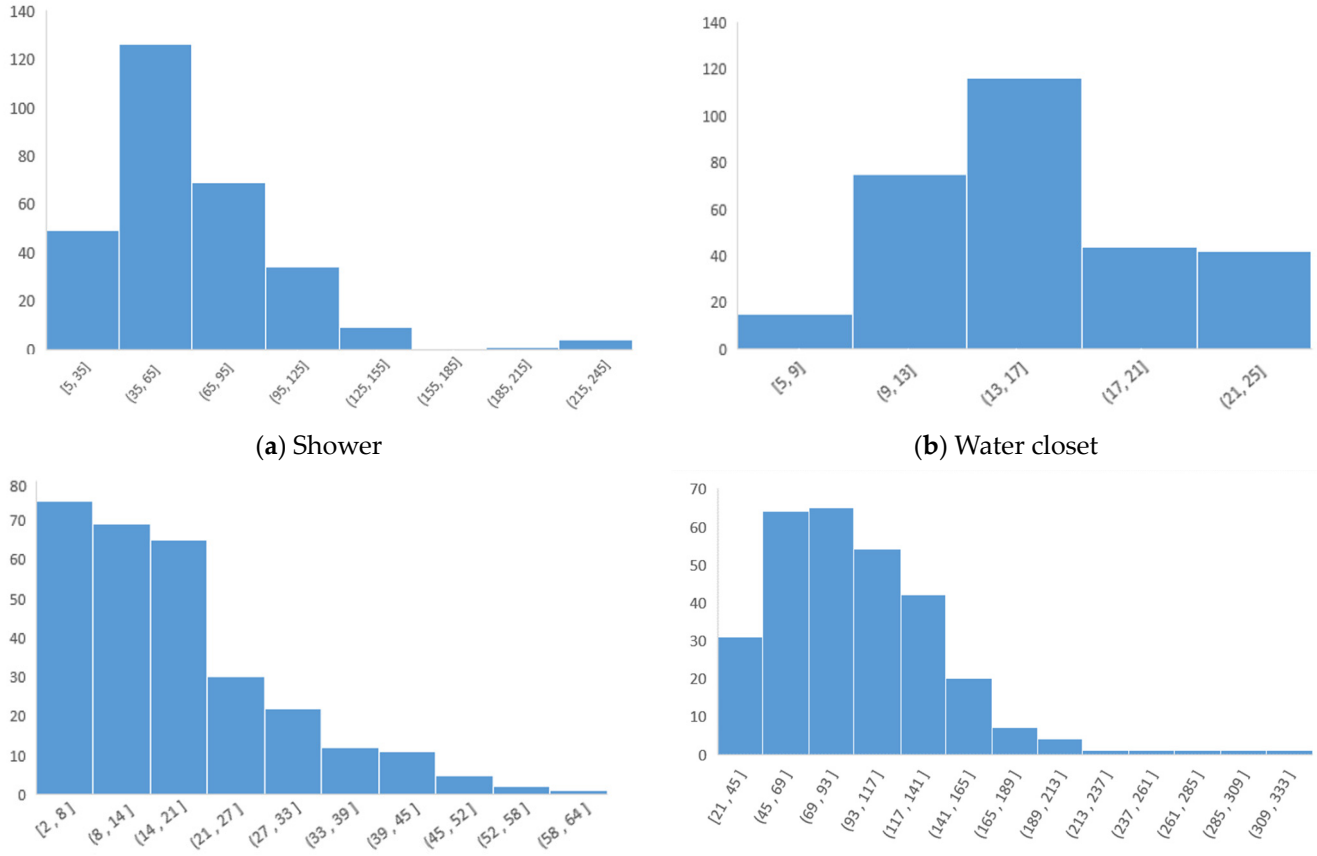


Figure 7. Probability density distribution of water consumption for each water appliance.

3.4. Water Demand by Hierarchy

Based on the analysis of water-use behaviors for hotel consumers, the hierarchy evaluation for each behavior has been conducted, with the results presented in Table 2. The conservative water-use behavior range represents water use that is encouraged without compromising the hotel service quality and consumer needs. The reasonable water-use behavior range corresponds to the habits of the majority of consumers, whereas the ex-

cessive water-use behavior range indicates water-use habits that surpass normal living requirements. Conservative, reasonable, and excessive water-use by hotel consumers was calculated using Formulas (1) to (4), where the water demand for excessive behavior can serve as a basis for estimating the water-saving potential of hotel consumers (Table 3). The analysis reveals that the conservative water demand of hotel consumers is 47.16 L/(person·d), and the excessive water demand is 141.20 L/(person·d). The excessive water-use demands for using showers, toilets, and faucets are more than 94.56, 20.00, and 26.64 L/(person·d), respectively.

Table 2. Hierarchical intervals for each water-use behavior.

Category of Water-Use Appliances	Water-Use Behaviors	Unit	Average Value	Conservative Water-Use Behavior Range	Reasonable Water-Use Behavior Range	Excessive Water-Use Behavior Range
Shower	Frequency of bathing	times	1.07	≤0.61	0.61–1.48	>1.48
	Duration per bathing	min	10.32	≤6.16	6.16–14.47	>14.47
Water closet	Frequency of toilet flushing	times	3.08	≤2.16	2.16–4.00	>4.00
Faucet	Frequency of washing up	times	1.94	≤1.52	1.52–2.36	>2.36
	Duration per washing up	min	0.98	≤0.39	0.39–1.56	>1.56
	Frequency of hand washing	times	3.49	≤2.48	2.48–4.49	>4.49
	Duration per hand washing	min	0.24	≤0.09	0.09–0.39	>0.39

Table 3. Conservation, rationalization and excessive water consumption by end-use appliances of hotel consumers.

Category of Water-Use Appliances	Unit	Range of the Demand for Conservative Water-Use Behavior	Range of the Demand for Reasonable Water-Use Behavior	Range of the Demand for Excessive Water-Use Behavior
Shower	L/(person·d)	≤29.46	29.46–94.56	>94.56
Water closet		≤10.80	10.80–20.00	>20.00
Faucet		≤6.90	6.90–26.64	>26.64
Total		≤47.16	47.16–141.20	>141.20

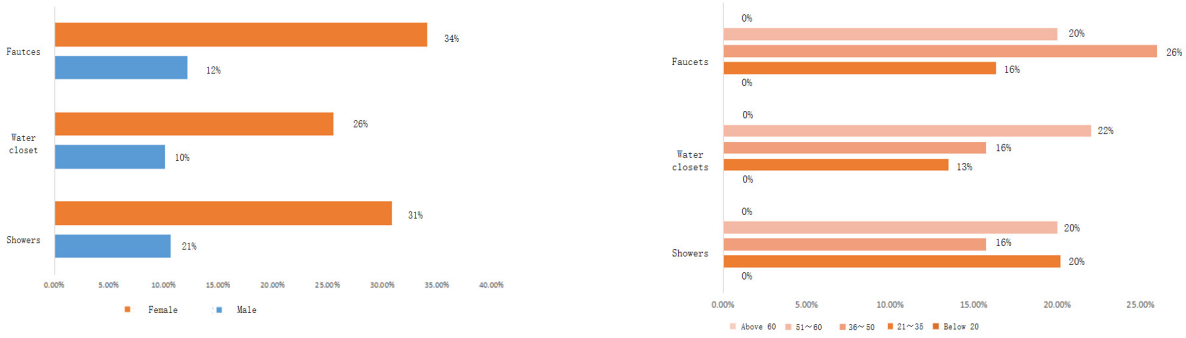
Among the various water-use appliances, faucets had the highest proportion of excessive water use (nearly 40%). Thus, among the different water-use behaviors of consumers, it is essential to focus on enhancing the water efficiency of faucets. Showers were the next major contributors to water consumption, whereas the proportion of excessive water use for water closets was relatively small. However, nearly 30% of consumers still adopted excessive water-use behaviors, as depicted in Figure 8. In general, hotel consumers have considerable potential for water conservation across various water-use appliances and behaviors.

The significant differences in water-use habits among consumers with different individual characteristics led to disparities in water usage for different appliances. According to the survey and analysis of excessive water use in different hotel consumer behaviors, as shown in Figure 9, the findings reveal that female consumers have a notably higher proportion of excessive water use than males. The proportion of excessive water used for bathing is three times that of males, making them the main target group for water conservation initiatives. Consumers under 20 and over 60 exhibit good water-use habits and strong water-saving awareness, with no excessive water-use behaviors. For bathing, consumers aged 21–35 and 51–60 possess considerable potential for water conservation. Consumers aged 51–60 have the largest proportion of excessive water use in toilet flushing behaviors,

whereas those aged 36–50 are a crucial group for personal hygiene water conservation, which includes washing up and hand washing.



Figure 8. Consumption of excessive water-use behaviors of different water appliances.



(**a**) Gender (**b**) Age

Figure 9. Consumption of excessive water-use by hotel consumers with different individual characteristics.

4. Discussion

Successfully managing water in hotels involves multiple stakeholders, including both hosts (hotel operators, management, and staff) and guests [16]. For hosts, the water efficiency of appliances plays a significant role in reducing water usage [34]. Given that showers account for approximately 63% of water consumption, focusing on improving shower systems could yield substantial water conservation benefits.

More importantly, since consumers are responsible for the majority of water use in hotels [35], reducing their discretionary water-use is expected to result in significant savings [36]. The study's findings reveal variations in the usage behaviors of different water appliances among consumers of varying ages and genders. Consistent with previous analyses of residential water use habits [12], females tend to exhibit higher frequencies and durations in various water use behaviors compared to males.

In addition, there are minor differences in specific frequencies and durations when compared to household water use. The quantity of excessive water-use for showering, water closets, and faucets in China's households is more than 48 L/(person·d), 24 L/(person·d), 21 L/(person·d), respectively [11]. This means that for the same activity, such as taking a shower, individuals in hotels consume significantly more water than they do at home. The reason might be that, since there is no additional cost for water usage while staying at a hotel, the duration of bathing for hotel guests is longer than in residential settings. Moreover, the relatively small differences regarding the results of water closets and faucets may be attributed to the fact that hotel guests typically spend a limited amount of time in their rooms, resulting in a lower frequency of use.

5. Conclusions

This study was grounded in a survey of water-use behaviors and demands of hotel consumers, developed a computational model for water consumption among hotel consumers, and examined the total water usage and characteristics of usage behavior for various water-use appliances by consumers with different traits.

The findings indicate that individuals with different characteristics have different habits in water use, which are primarily attributed to differing habits in water usage and conservation. In terms of water consumption, the daily water use by consumers in hotels is predominantly within the range of 45–141 L/(person·d), with showers being the top consumers, followed by faucets and water closets with fairly equal water usage. Utilizing the water hierarchy theory and evaluation techniques, this study delineates the usage behavior levels for each water-use appliance and calculates the conservative water-use behavior demand for hotel consumers at 47.16 L/(person·d) and excessive water demand at 141.20 L/(person·d). Among the various water-use appliance usage behaviors, faucets account for the largest share of excessive water use, and female consumers represent the group with the most significant potential for water conservation among hotel consumers. Consumers under 20 and over 60 years of age exhibit better water-use habits; at the same time, the frequency of these two groups accounts for a smaller proportion of hotel consumers and has relatively less potential for water conservation. Additionally, owing to differing water-use habits, the main target groups for water conservation vary across the usage behaviors of different water fixtures.

This study identified the primary targets for water conservation in each water appliance usage behavior based on research findings. It offers targeted approaches to enhance water-use efficiency in hotels, which is crucial for standardizing water management practices within the industry. This lays the groundwork for further analysis and forecasting models concerning the rational use of water by hotel consumers with different individual characteristics and for conducting a water-saving benefit analysis of various water fixtures. It also serves as a reference for other industries to conduct research on the water demand hierarchy.

6. Limitations

The present study has several limitations that warrant discussion. Firstly, the sample size, while representative, may not fully capture the diversity of the population. This could introduce a sampling bias, potentially affecting the generalizability of our findings. Secondly, the reliance on self-reported data may be subject to social desirability bias, which could influence the accuracy of the responses. Finally, due to the substantial water usage in hotels and their rapid development in recent years, this study selects them as the research subject. Within this context, because consumers are responsible for the majority of water use in hotels, the study primarily concentrates on the behaviors of consumers, which means that other water usage cases in hotels, such as water demand in kitchens, cafeterias, fitness gyms, and cleaning activities are not taken into account. These aspects all require further refinement in subsequent research.

Author Contributions: Conceptualization, X.B.; methodology, Y.B.; data curation, M.H.; original draft preparation, R.C.; formal analysis, L.K.; review and editing, J.L. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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